rotation due to causes of this kind, similar considerations arise.* A slight subsidence, due to shrinkage around the equator, unless it extended downward a long way toward the Earth's centre, would have negligible direct effect on the moment of inertia and, therefore, on the length of the day; but if it were under sea it would involve transference of water from regions nearer the Earth's axis, in order to make up the deficiency, and if the equatorial regions were all under water, a contraction of 50 cm. in equatorial radius would in this way alter the length of the year by an amount of the order of half a second of time, which would be astronomically of high importance.]

Notes on Observations of Sun and Stars in some British Stone Circles. Fourth Note.—The Botallek Circles, St. Just, Cornwall.

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(Received December 8, 1908,—Read January 14, 1909.)

Borlase, in his "Antiquities of Cornwall" (p. 199), published in 1769, refers to what he terms "the curious cluster" of circles at Botallek, the seeming confusion of which led him to write "I cannot but think that there was some mystical meaning, or, at least, distinct allotments to particular uses."

Fortunately for science, he accompanies his account with a plan evidently carefully prepared (fig. 1), which is now the only thing that remains; every stone has been utilised in building an engine house, or in other ways. Only the site is shown on the ordnance map.

As the "cluster" of circles exceeds in elaboration anything of the kind with which I am acquainted, it was of great interest to see if anything could be made of it in the light of other researches in Cornwall already referred to in previous communications to the Royal Society.† The first point of

* Lord Kelvin, *loc. cit.*, § 38.

† 'Roy. Soc. Proc.,' A, vol. 76, 1905, p. 177; A, vol. 77, 1906, p. 465; A, vol. 80, 1908, p. 285.

inquiry concerned the N. point given on the plan—whether it was true or magnetic. A perusal of Borlase's volume showed that he was fully acquainted with the necessity of referring in such descriptions to the true north, instead of, as he says, "such an inconstant and fluctuating index as the

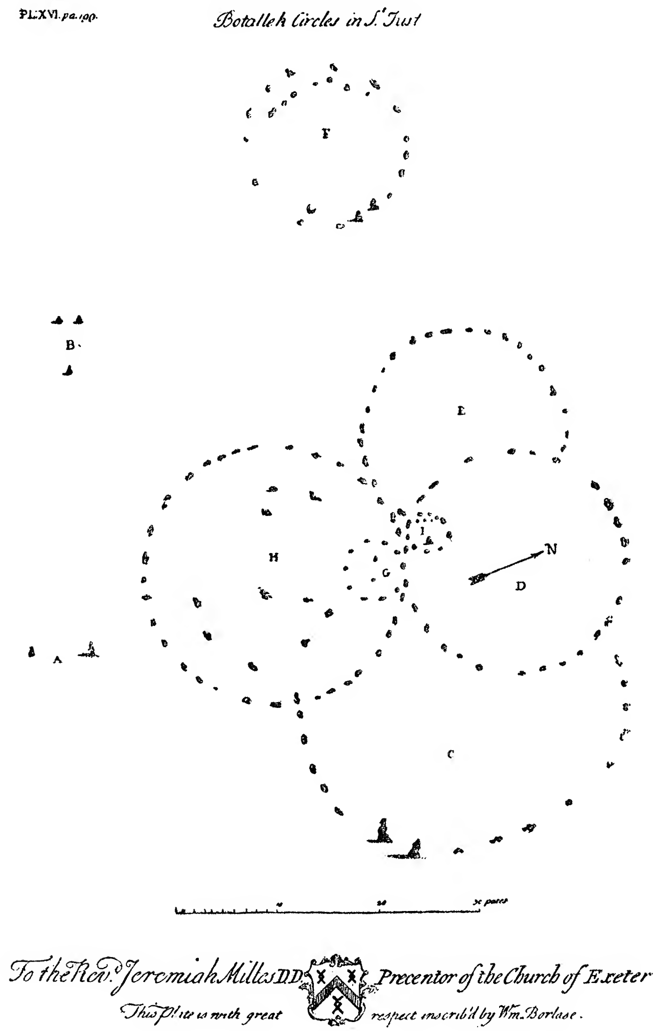

Fig. 1.

declination of the needle, which is not only different in different places, but varies also at different times in one and the same place" (p. 115).

When the point was settled, it became evident, when the circles were completed and lines drawn from centre to centre, that approximately the same azimuths were in question as those before noted.

Borlase does not give the heights of hills for the various azimuths to complete his plan. I therefore asked Mr. Thomas, an active member of the Cornish Society for the Astronomical Study of Ancient Monuments, to observe them for me. Taking Borlase's orientation as being near the truth, lines were drawn joining up the approximate centres of the various circles and a list of the various azimuths was sent to Mr. Thomas, who was good enough to comply with my request at once.

Among the azimuths were two, the first from the approximate centre of the circle F to the approximate centre of E, N. 83° E., and the second, from the approximate centre of F to that of H, S. 66° E. In sending his results to me Mr. Thomas remarked that the former line passes over the Carn Bean barrow and the latter passes $2\frac{1}{4}°$ to the N. of the Goon Rith barrow; thus the azimuth of the Goon Rith barrow would be S. $63\frac{3}{4}°$ E.

It struck me that this circumstance would enable us to check the accuracy of Borlase's N. point. It is much easier to make a careful survey of a monument than to indicate its true orientation, so some slight error has to be expected. Borlase in all probability employed a compass in making his surveys and was, therefore, dependent, for accurate orientation, on a knowledge of the value for the local magnetic variation; for this he would have to depend upon the results of some general survey. Even at the present day it is a matter of great uncertainty to obtain the variation for any one place without making a special determination on the spot, and we should expect a possible error of several degrees in any orientation made in Borlase's time.

The two directions to two still existing monuments pointed out by Mr. Thomas are common to Botallek and other monuments in Cornwall, we seem justified therefore in accepting them as such. On this assumption, Borlase's orientation was true, and not magnetic, and, also, was not far from the mark.

The next step was to make a very careful determination of the centres of the circles and it was found that the line, centre of F to centre of H, coincided with the line S. 63° 45′ E. from the former to the Goon Rith barrow. In other words, the difference between the azimuth we had provisionally determined from the circles and that of Goon Rith barrow was due to an error of centring, and no doubt was left that the line between the centres of F and H was really directed to the barrow. Similarly the line N. 83° E. joining the centres of F and E was directed to the Carn Bean barrow. Both these lines were recognised as familiar, giving, approximately, the November sunrise and the heliacal rising of the Pleiades in May respectively. In the case of the S.E. azimuth there is an alternative

explanation of the sight-line. Both in Cornwall and Wales we have found that azimuth-marks (barrows, etc.), were sometimes erected so that they gave the direction of sunrise a fortnight or three weeks before the critical date. I therefore decided to adopt the Pleiades azimuth, N. 83° E., as the fundamental line by which to fix the N. point, and it followed that Borlase's N. point was less than 3° to the west.

Working on this basis, I joined up the centres of the circles, as shown on the plans (figs. 2 and 3), and carefully measured the resulting azimuths. These I sent to Mr. Thomas, asking him if the slight modifications that I had introduced had sensibly altered his values for the corresponding angular elevations. After a second series of observations, he replied that the elevations were the same for the modified azimuths as they were before.

It at once became obvious that the alignments divided themselves naturally into two groups—the one erected for the observations of May-year, the other for solstitial, phenomena—and with each group there is associated a clock-star which affords a means of determining the approximate date of that group. For this reason I give two separate plans (figs. 2 and 3) showing the separate

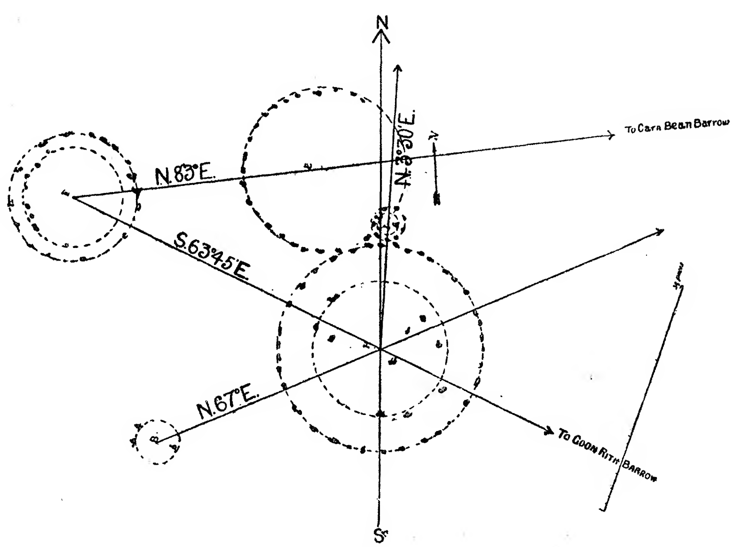

FIG. 2.

groups of alignments, and two separate tables giving the respective results. I will deal with the May-year circles first (fig. 2) :—

May-year Alignments at Botallek (lat. 50° 8′ N.).

Alignment.	Azimuth.	Hill (Mr. Thomas's) measures.	Declination.	Object.	Date.
	° ′	° ′	° ′		
Centre of circ. B to cent. of circ. H	N. 67 0 E.	3 0	16 31 N.	May sun	May 6; Aug. 7
Cent. of circ. F to cent. of circ. H to Goon Rith barrow	S. 63 45 E.	2 44	14 43 S.	Nov. sun (possibly a warner)	Nov. 2; Feb. 10
Cent. of circ. F to cent. of circ. E to Carn Bean barrow	N. 83 0 E.	3 35	7 2 N.	Pleiades (warning May sun)	1680 B.C.
Cent. of circ. H to cent. of circ. I	N. 3 30 E.	0 0	39 14 N.	Arcturus (clock-star)	1730 B.C.

These results agree in a wonderful way with the May-year results previously obtained from the study of other Cornish circles, and to illustrate this I bring together a selection of the results previously published :—

Similar May-year Alignments in Cornwall (for comparison).

Monument.	Lat. N.	Alignment.	Azimuth.	Hill.	Declination.	Object.	Date.
	° ′		° ′	° ′	° ′		
Merry Maidens	50 4	Circ. to Fougou ...	N. 64 0 E.	0 30	16 21 N.	May sun	May 5; Aug. 7
Boscawen-Un	50 5	„ stone.........	S. 66 30 E.	1 0	14 32 S.	Nov. sun	Nov. 2; Feb. 10
The Hurlers ...	50 31	S. circ. to N.E. stone	N. 78 47 E.	0 12	7 23 N.	Pleiades	1610 B.C.
Trippet stones	50 33	Cent. of circ. to Rough Tor	N. 15 0 E.	1 30	39 1 N.	Arcturus	1700 B.C.

Examination of fig. 2 shows that the azimuths given in the table are exactly those obtained by joining up the true centres of the circles and adopting the N.—S. line derived from Mr. Thomas's two measures of direction. The results certainly justify the 3° change of the orientation.

The Solstitial Year.

Joining up the centres of H, G, D, and C, as shown in fig. 3, we obtain the results given in the following table, results which are obviously connected *inter se* and with the solstitial year :—

Solstitial Alignments at Botallek (lat. 50° 8′ N.).

Alignment.	Azimuth.	Hill (Mr. Thomas's) measures.	Decli-nation.	Object.	Date.
	° ′	° ′	° ′		
Cent. of circ. H to cent. of circ. C	N. 53 0 E.	1 45	23 41 N.	Solstitial sun (summer)	
Cent. of circ. D to cent. of circ. C	S. 49 30 E.	1 35	23 44 S.	Solstitial sun (winter)	
Cent. of circ. H to cent. of small circ. G	N. 16 0 E.	0 0	37 28 N.	Arcturus (clock-star)	1420 B.C.

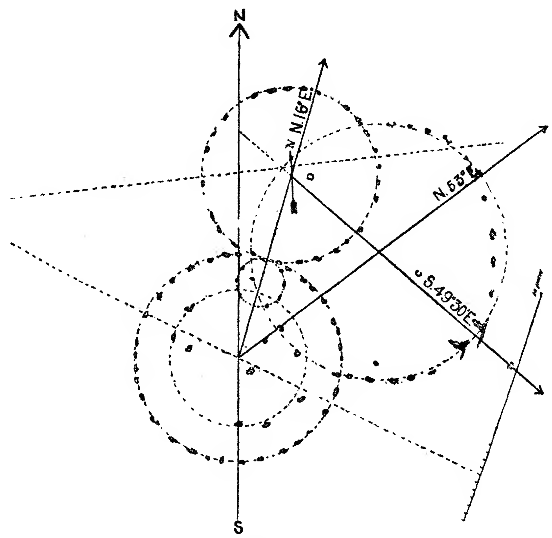

Fig. 3.

As before, I give a selection from previous results, showing that the alignments we are now dealing with have become familiar by reason of their occurrence at the Cornish monuments investigated earlier :—

Similar Solstitial Alignments in Cornwall (for comparison).

Monument.	Lat. N.	Alignment.	Azimuth.	Hill.	Declina-tion.	Object.	Date.
	° ′		° ′	° ′	° ′		
Boscawen-Un ...	50 5	Circ. to Fine Menhir	N. 53 30 E.	2 23	23 59 N.	Solstitial sun (summer)	
The Hurlers ...	50 31	N. circ. to S.E. stone	S. 50 50 E.	1 18	24 17 S.	Solstitial sun (winter)	
Tregeseal.........	50 9	Longstone to Chûn Castle	N. 23 30 E.	1 35	37 9 N.	Arcturus	1350 B.C.

It will probably be remarked that I attach no dates to these solstitial sight-lines. This is because the data available are not sufficiently certain to justify dating. The solstitial variation takes place so slowly and between such restricted limits that, until the most accurate observations possible have been made at a monument, it is merely conjecture to apply a date; only at Stonehenge, so far, has this been possible. Under the Botallek conditions, a difference of half a degree in the azimuth would produce a variation of more than 2000 years in the resulting date, and one cannot assume that accuracy in the present case.

From the results given above it is evident that in this "curious cluster" of circles at Botallek we have an epitome of the chief sight-lines found in Cornwall. May-year sun, clock-star, warning-star, and solstitial sun are all represented.

The occurrence of star circles is fortunate, as it enables us to attempt to arrange the groups in order of date. As shown above, the May-year group, F, H, B, and E, with the clock-star circle I, was probably the first, by something like 300 years, to be erected, and it should be noted that the date for the Pleiades circle E is coincident, within our probable error, with the date of the clock-star alignment H—I.

Borlase's plan (fig. 1) affords us evidence on this point, for it shows that the circles F, H, and I are associated by being made up of two concentric rings of stones. The fact that stones were obviously taken from the periphery of E when D was built shows that E, too, was an earlier circle than D; our results associate E with the May-year and D with the solstitial group. The incompleteness of B suggests partial demolition prior to Borlase's survey, whilst its relatively smaller size suggests that what remains may have formed the interior ring of a double circle.

Conclusions.

The cluster of circles at Botallek, St. Just, Cornwall, was erected for astronomical observations, and forms an epitome of the principal alignments to sun and stars previously found in Cornwall and other parts of the British Isles. The results justify the azimuths obtained from Borlase's plan and show that his orientation of the plan is not more than 3° in error.

It appears that in this cluster we have two distinct groups of alignments, one associated with the May-year worship, the other associated with the later solstitial-year ritual.

As a clock-star alignment occurs in each group, we are able to determine that the May-year worship preceded the solstitial-year by something like

300 years, the approximate dates being 1700 B.C. and 1400 B.C. respectively. This sequence is confirmed by the structure of the circles themselves as plotted by Borlase.

I have to thank Mr. Thomas for his local observations, and Mr. Rolston, of the Solar Physics Observatory, for assistance in the discussion and computing the various declinations.

On the Passage of Röntgen Rays through Gases and Vapours.

By J. A. Crowther, B.A., Fellow of St. John's College, Cambridge, Mackinnon Student of the Royal Society.

(Communicated by Prof. Sir J. J. Thomson, F.R.S. Received December 22, 1908, —Read January 14, 1909.)

Introduction.

The present work is a continuation of a previous research on the Secondary Röntgen Radiation from Gases and Vapours.* It was there shown that while for gases and vapours containing only elements of small atomic weight the secondary radiation was simply proportional to the density of the gas, those containing elements of higher atomic weight, and notably compounds of arsenic and bromine, gave off quantities of secondary radiation greater out of all proportion than what would be expected from their density. It was also shown that while the secondary radiation from the first class of substances had approximately the same penetrating power as the primary rays producing it, the secondary radiation from the second class was generally of a considerably softer character. A third class of substances, including stannic chloride and methyl iodide, gave off secondary rays, the hardness of which was equal to that of the primary, while their intensity, which, however, varied with the hardness of the primary rays, was intermediate between that of the first and second classes.

It was thought that a further investigation of the phenomena attending the passage of Röntgen rays through these different classes of gases and vapours might possibly lead to some interesting results.

* 'Phil. Mag.,' [6], vol. 14, p. 653, 1907.